DTU Library

Energy Analysis of the Ductless Personalized Ventilation

Lelong, Cyril ; Dalewski, Mariusz; Melikov, Arsen Krikor

Published in:
Proceedings of 11th REHVA World Congress and the 8th International Conference on Indoor Air Quality, Ventilation and Energy Conservation in Buildings

Publication date:
2013

Energy Analysis of the Ductless Personalized Ventilation

Cyril Lelong[#1], Mariusz Dalewski[#2], Arsen K. Melikov[#3]

[#]*International Centre for Indoor Environment and Energy, Department of Civil Engineering, Technical University of Denmark (DTU), Kgs. Lyngby, Denmark*

[1]cyril.lelong@gmx.fr

[2]mzda@byg.dtu.dk

[3]akm@byg.dtu.dk

Abstract

This study explores the impact of different occupancy profiles on the potential energy savings due to using ductless personalized ventilation (DPV) combined with displacement ventilation. Energy simulations were performed with the dynamic simulation software IDA-ICE in order to investigate optimal energy efficient strategies for implantation of DPV in practice. The impact of using DPV on annual energy use has been studied for different occupancy profiles in cold climates. The results suggest that using DPV combined with displacement ventilation may significantly reduce building energy use while providing good air quality and thermal comfort for the occupants. Matching DPV use with occupants' presence at their workplaces may allow reducing the energy use of DPV significantly.

Keywords - Energy saving; air quality; thermal comfort; occupancy, energy simulation

1. Introduction

The main objective of the ductless personalized ventilation (DPV) combined with displacement ventilation (DV) is to suck the fresh and clean air distributed over the floor area by DV and to supply it under individual control directly to the breathing zone of the occupants. Personalized ventilation systems may improve inhaled air quality, thermal comfort and work performance of occupant, as well as decrease the prevalence of sick building symptom (SBS) symptoms [1]. Additionally, as it has been demonstrated by Dalewski et al. [2], the use of DPV system can allow increasing indoor air temperature while providing acceptable thermal comfort among occupants. Therefore, potential energy savings can be achieved by reducing cooling energy demand in summer. So far, little is known about possible impact of using DPV on energy use and energy saving strategies. This is studied and presented in this paper.

2. Methods

Dynamic simulations were performed with the IDA Indoor Climate and Energy software (ICE). A reference room was created in order to study energy use of DPV systems and the impact of different occupancy profiles on total energy use. The reference room was an open-plan office with a floor surface area of 6 m x 20 m and a ceiling height of 3 m. The external wall was considered to be well insulated (U_{total} = 0.208 W/m^2·K) and had a window area of 36 m^2 (window height = 1.8 m, width = 20 m), that corresponded to 60 % of the external wall area. The window had an overall U-value of 1.2 W/m^2·K and faced south. There was a shading device composed of blinds between the window panes that were activated when the incident light on the windows was higher than 200 W/m². The shading device had a multiplier for a total shading coefficient equal to 0.39 that limited the solar gains to pass through the windows. All internal walls in this study room were considered adiabatic and the effect of the thermal mass was taken into account.

Design parameters for the ventilation system were chosen in order to respect the values for the Category I of the indoor environment as defined in the EN15251 [3]. For the reference case (case 1), the maximum and minimum air temperature that was allowed in the room was 26 °C and 21 °C, respectively, during occupied hours (from Monday to Friday, from 6:00 to 17:00). During the weekends (Saturday and Sunday) and night-time (from 17:00 to 6:00) the indoor air temperature set point was at a minimum of 12 °C in winter and at a maximum of 40 °C in summer. In the following cases the upper indoor air temperature limit was modified, as shown in Table 1, in order to study its influence on energy use. The total volume ventilation in all cases was provided by displacement ventilation system controlled by a central air handling unit (AHU). A variable air volume (VAV) system was used with indoor air temperature control. The AHU was in operation during occupied hours, i.e. from Monday to Friday, from 6:00 to 17:00. The humidity was controlled by the AHU in order to keep the values between 20 and 80 %. The supply air temperature control was a function of the outdoor air temperature as defined with the two profiles in the Figure 1.

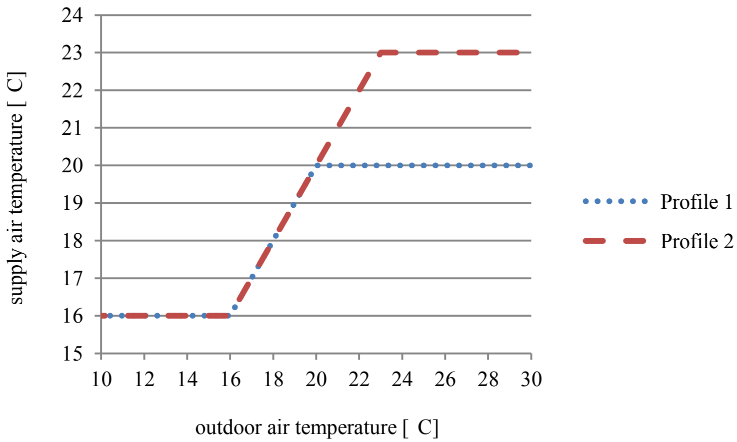

Fig. 1 Supply air temperature as a function of outdoor air temperature

At full occupancy, 12 occupants were present in the room from Monday to Friday and the total heat produced per occupant was 125 W. The building was occupied during all the year except for Saturdays and Sundays that were considered to be days off. Three occupancy profiles were studied in order to understand the impact of occupancy on the total energy consumption. Occupancy profile 1, shown in Figure 2, assumes that all employees are always present at work from 8:00 to 17:00 with one-hour break between 12 and 13. The Figure 3 corresponds to the occupancy profile 2 made according to EN 15232 [4]. The occupancy profile 3 shown in Figure 4 was created according to data measured by Nobe et al. [5] in a Japanese 52-story office building where 240 workstations were observed during one week.

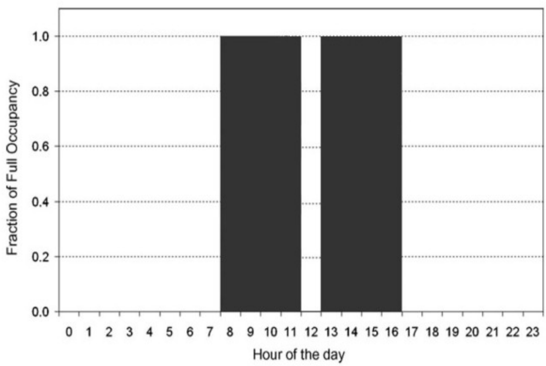

Fig. 2 Occupancy profile 1

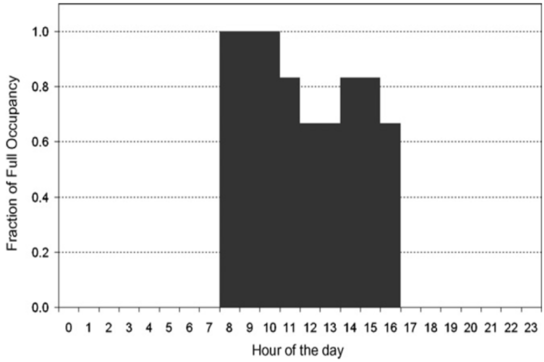

Fig. 3 Occupancy profile 2

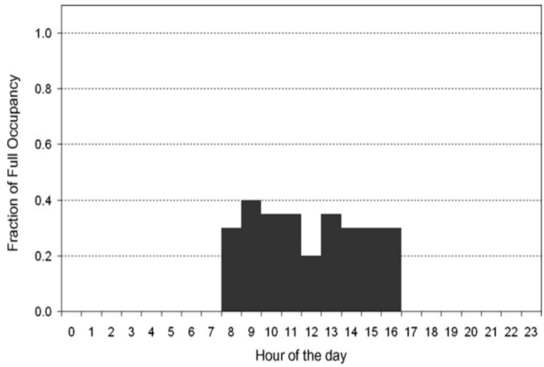

Fig. 4 Occupancy profile 3

The heat load due to diverse electric office equipment was 6 W/m² and was activated during the occupied hours. The heat load due to lightning was 10 W/m² during working hours (from 8:00 to 17:00), outside this period the light was switched off.

3. Results and Discussion

In the following the impact of occupancy profiles and using DPV on total energy use has been discussed. The energy use of DPV system is due to the fan that supplies air to the breathing zone of each occupant. This energy use may vary depending on the supply air flow rate and the time for how long DPV system is in use. Simulations were carried out with DPV fan power ranging from 0 (DPV off), 10 and 20 W. DPV was considered to be in operation throughout the year, although during cold months, when indoor air temperature is within a comfortable range, using DPV may not be necessary from thermal comfort point of view. However using DPV improves inhaled air quality and this criterion was chosen. DPV was only in use when the occupants were present at their work stations so DPV usage patter followed occupancy profiles. All simulated cases are presented in Table 1.

Table 1. Simulated cases

case	θ UP min [°C]	θ UP max [°C]	supply air temperature	occupancy	DPV power [W]
1	21	26	profile 1	Fig. 1	0
2	21	26	profile 1	Fig. 2	0
3	21	26	profile 1	Fig. 3	0
4	21	29	profile 2	Fig. 1	0
5	21	29	profile 2	Fig. 2	0
6	21	29	profile 2	Fig. 3	0
7	21	29	profile 2	Fig. 1	10
8	21	29	profile 2	Fig. 1	20
9	21	29	profile 2	Fig. 2	10
10	21	29	profile 2	Fig. 2	20
11	21	29	profile 2	Fig. 3	10
12	21	29	profile 2	Fig. 3	20

θ UP min - lower limit of indoor air temperature
θ UP max - upper limit of indoor air temperature

Figure 5 shows energy demand in a reference office located in Copenhagen, Denmark, for three different occupancy profiles, with DPV not in use, upper limit of indoor air temperature was 26 °C for cases 1-3, and 29 °C for cases 4-6.

Figure 6 and 7 show energy use with DPV in use and with upper limit of indoor air temperature of 29 °C. Case 4, with DPV turned off, is presented as a reference scenario.

Variation of occupancy and DV only

The impact of occupancy on energy use was studied with upper limit of indoor air temperature of 26 °C and 29 °C. Lower limit of indoor air temperature was 21 °C. Supplied air temperature was controlled according to outdoor air temperature as shown in Figure 1. Every person during typical office work generates about 125 W of heat and this, together with associated heat gains from office equipment, may significantly increase heat load especially in highly occupied spaces. Internal heat gains associated with occupancy may reduce heating demand in winter, however adverse effects will be observed in summer with increased demand for cooling energy. The following simulations investigated whether different occupancy profiles will have a positive or negative impact on energy demand. The assumption was made that when people are not present at their desks, they are not in the room, either. Moreover, when the occupants are absent, the associated internal gains generated by the office equipment are not considered as well.

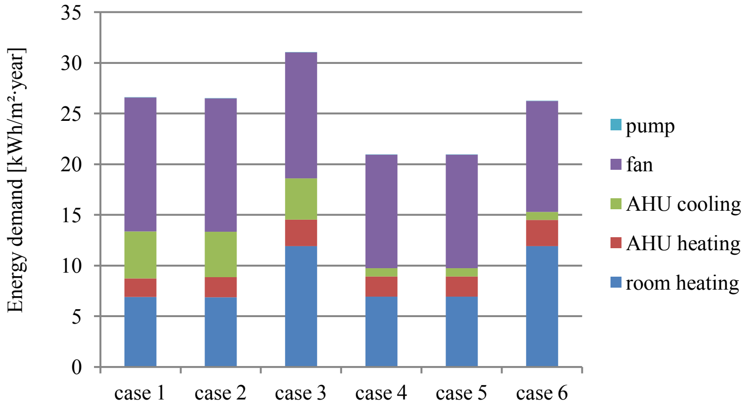

Fig. 5 Total energy demand with DV only for different occupance profiles at indoor air temperature of 26 °C (cases 1, 2 and 3) and 29 °C (cases 4, 5 and 6)

As can be seen in Figure 5, in cases 1 and 2 energy demand is similar with 26.6 and 26.5 kWh/m²·year, respectively, for upper indoor temperature limit of 26°C. The occupancy profiles 1 and 2 corresponding to cases 1 and 2 are too similar to cause any significant differences in heating and cooling energy requirements. Case 3 associated with the occupancy profile 3 defined by Nobe et al. [5] have significantly higher energy demand than other presented cases. Low occupancy (maximum 40 %) and low use of electric equipment increased considerably the total energy demand. Low occupancy caused a slight reduction in cooling energy use compared to the other two occupancy profiles (cases 1 and 2) but also a significant increase of the heating energy use in the room. For a building located in a climate that generally requires more heating than cooling, e.g. Northern European, the decrease of occupancy entails a general increase of energy use. Results reviled that significant energy savings can be achieved by increasing the upper indoor air temperature limit. Cases 3 and 6, with similar control strategy for supply air temperature (shown in Figure 1) have an energy use of 31.0 and 26.2 kWh/m²·year respectively, representing a decrease of 16 % when the upper indoor air temperature limit increased from 26 °C to 29 °C. Indeed, the increase of the upper limit temperature permits to reduce the energy needed for cooling considerably even in relatively cold Danish climate. In such case, the installation of DPV, that permits to increase to room temperature while providing good thermal comfort for occupants, might be beneficial.

Variation of occupancy and use of DPV

The objective was to study the impact of using DPV at different occupancy profiles, described in the section above, on energy use in the reference office. According to Dalewski et al. [2], using ductless personalized ventilation improves thermal comfort of occupants if indoor air temperature is higher than suggested in present standards. Increasing indoor air temperature by 3 °C, i.e. to 29 °C, and providing occupants with DPV can bring their thermal sensation to the similar level like in spaces with indoor air temperature of 26 °C.

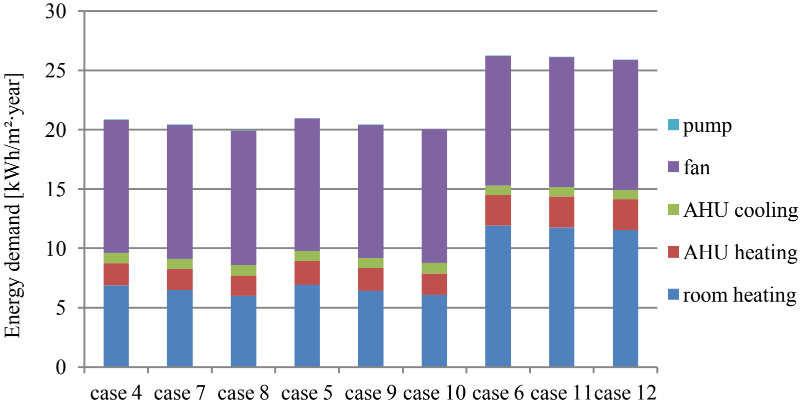

Fig. 6 Energy demand for different occupancy profiles and DPV fan power at indoor temperature of 29 °C

The figure 6 shows the energy demand for different occupancy profiles and DPV fan power. As seen in this figure, the use of DPV at a power of 20 W permits to slightly decrease the energy use. For a building located in Copenhagen, the heating energy use is one of the most important parts of the total energy demand. Consequently, using DPV and thus increasing heat gains in the room will reduce heating energy demand. However, this figure shows the energy demand related only to heating, cooling, and ventilation without presenting energy used by additional processes like lightning, office equipment or DPV systems. The total energy use in the building, taking into account all major energy-use processes e.g. office equipment and lightning, is shown in Figure 7.

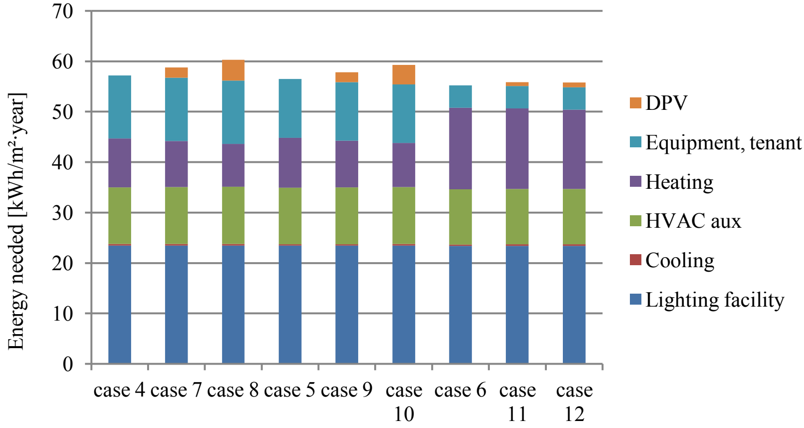

Fig. 7 Total energy demand for different occupancy and DPV power at indoor temperature of 29 °C

Contrary to what is shown in Figure 6, cases 6, 11 and 12, corresponding to the occupancy profile 3, show lower energy demand than occupancy profiles 1 and 2. Indeed, the case 12 represents a total consumption of 56.3 kWh/m²·year whereas it is 60.3 kWh/m²·year and 59.3 kWh/m²·year for cases 8 and 10. These 4 kWh/m²·year of difference between cases 8 and 12 represent a decrease by 7 %. It can be seen on the Figure 7 that even if the heating energy demand is superior for case 12 in comparison to cases 8 and 10, the total electricity demand (e.g. office equipment, DPV) is lower.

The results in Figure 7 show that if the actual occupation is taken into account, i.e. occupancy profile 3, it is possible to significantly reduce the power consumed by these devices. This means that besides the fact to install DPV in order to reduce energy use by increasing the maximum indoor air temperature, it is also important to control the use of DPV in order to limit electricity use by DPV fans.

4. Conclusions

Increasing the upper air temperature limit allowed to significantly reduce the cooling energy use. At the same time occupants can be provided with better thermal comfort and inhaled air quality by using DPV. For a building located in hot climate energy savings might be higher.

For a cold climate, such as in Copenhagen, the control of the DPV based on the real occupancy profile may reduce DPV energy demand significantly. By having DPV turned on only when occupants are present at their workstations the energy demand can be reduced by nearly 7 %.

5. References

[1] A.K. Melikov, Personalized ventilation, Indoor Air 14 (Suppl. 7) (2004) 157–167.
[2] M. Dalewski, M. Veselý, A.K. Melikov, Human response to ductless personalized ventilation coupled with displacement ventilation, in: Proceedings of Healthy Buildings 2012, 8-12 July 2012, Brisbane, session 1A, paper 1A.1
[3] CEN (European Committee for Standardization), EN 15251-2007, Criteria for the Indoor Environment Including Thermal, Indoor Air Quality, Light and Noise, European Committee for Standardization, Brussels, Belgium, 2007.
[4] CEN (European Committee for Standardization), EN 15232-2006, Calculation Methods for Energy Efficiency Improvements by the Application of Integrated Building Automation Systems, European Committee for Standardization, Brussels, Belgium, 2006.
[5] T. Nobe, S. Tanabe, S. Lee, Y. Tomioka, Investigation of seat occupancy rate in office, in: Proceedings of Roomvent 2002, Copenhagen, Denmark, pp. 289–292.